US006003968A

United States Patent [19]

Kozawa

[11] Patent Number: 6,003,968

[45] Date of Patent: Dec. 21, 1999

[54] **INK JET HEAD**

[75] Inventor: Hirokazu Kozawa, Aichi-ken, Japan

[73] Assignee: Brother Kogyo Kabushiki Kaisha, Nagoya, Japan

[21] Appl. No.: 08/745,836

[22] Filed: Nov. 8, 1996

[30] **Foreign Application Priority Data**

Nov. 20, 1995 [JP] Japan 7-326548

[51] Int. Cl.[6] B41J 2/135; B41J 2/14

[52] U.S. Cl. 347/20; 347/70; 347/71

[58] Field of Search 347/70, 71, 20

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,935,086 6/1990 Baker et al. 156/246
5,376,856 12/1994 Takeuchi et al. 310/328
5,439,728 8/1995 Morozumi et al. 428/136
5,473,216 12/1995 Brosig et al. 310/346

FOREIGN PATENT DOCUMENTS

6-79871 3/1994 Japan .

Primary Examiner—John Barlow
Assistant Examiner—Christina Annick
Attorney, Agent, or Firm—Oliff & Berridge, PLC

[57] **ABSTRACT**

An ink jet head including a diaphragm, cavity plate, piezoelectric element, a nozzle plate and a base plate. The adhesive layer for bonding the diaphragm to the cavity plate is formed by an adhesive agent which develops glass transition at a head temperature. The adhesive layers for bonding the piezoelectric element to the diaphragm, the cavity plate to the nozzle plate, and the piezoelectric element to the base plate are each formed by an adhesive agent which does not develop glass transition at the head temperature.

17 Claims, 5 Drawing Sheets

	COMPONENTS WITH LARGE DIFFERENCE IN THERMAL EXPANSION COEFFICIENTS PES AND ALUMINA		COMPONENTS WITH SMALL DIFFERENCE IN THERMAL EXPANSION COEFFICIENTS PZT AND ALUMINA	
	KEPT AT 125°C	THERMAL CYCLE REPEATED	KEPT AT 125°C	THERMAL CYCLE REPEATED
HIGH Tg TYPE ADHESIVE (GLASS TRANSITION TEMPERATURE : HIGHER THAN 125°C)	○	×	◎	◎
MEDIUM Tg TYPE ADHESIVE (GLASS TRANSITION TEMPERATURE : 85°C TO 125°C)	△	×	△	○
LOW Tg TYPE ADHESIVE (GLASS TRANSITION TEMPERATURE : LOWER THAN 85°C)	△	○	△	○

adhesive absorbs thermal
stress differences between
membrane + actuator

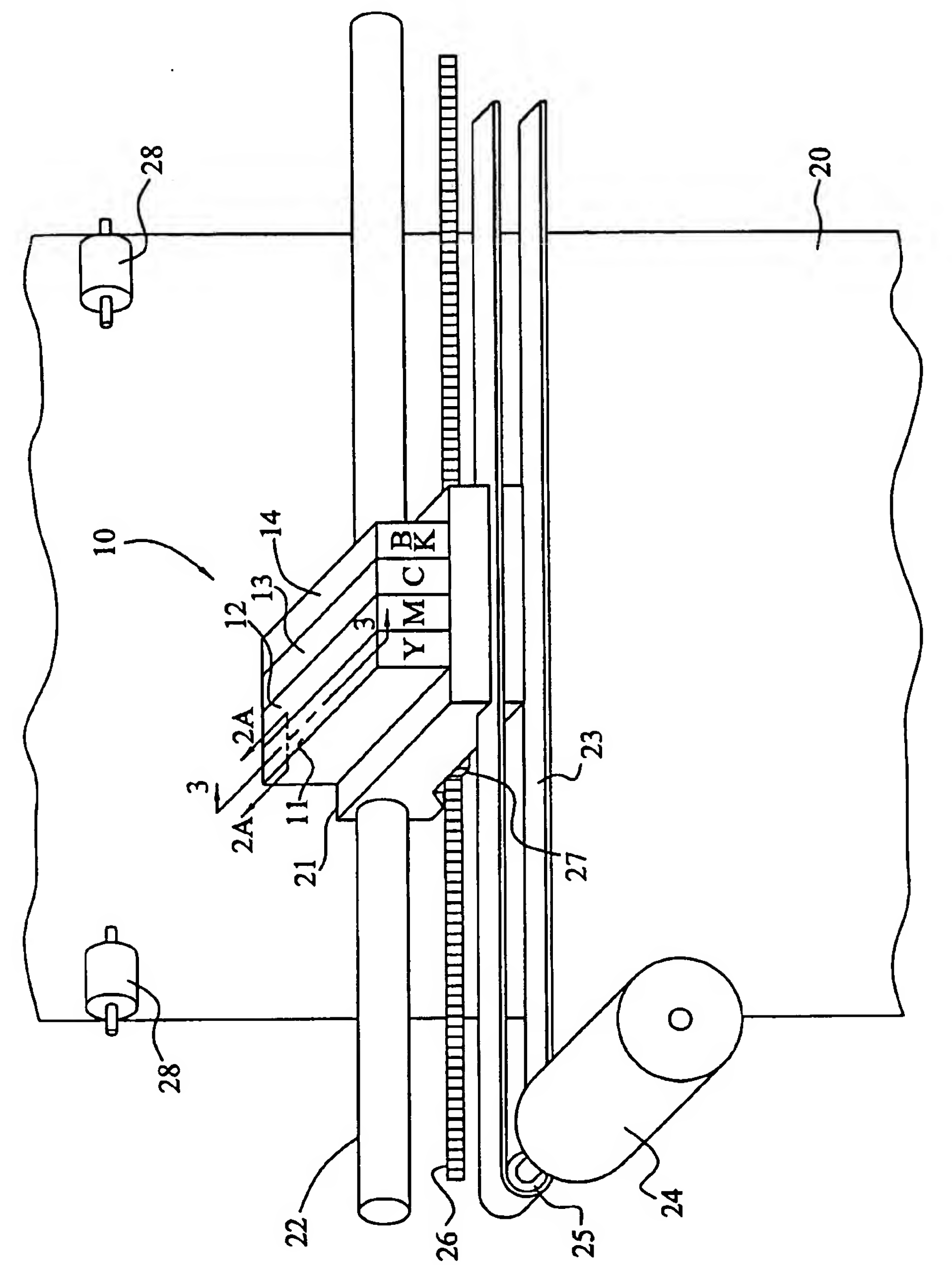

Fig. 1

Fig. 2A

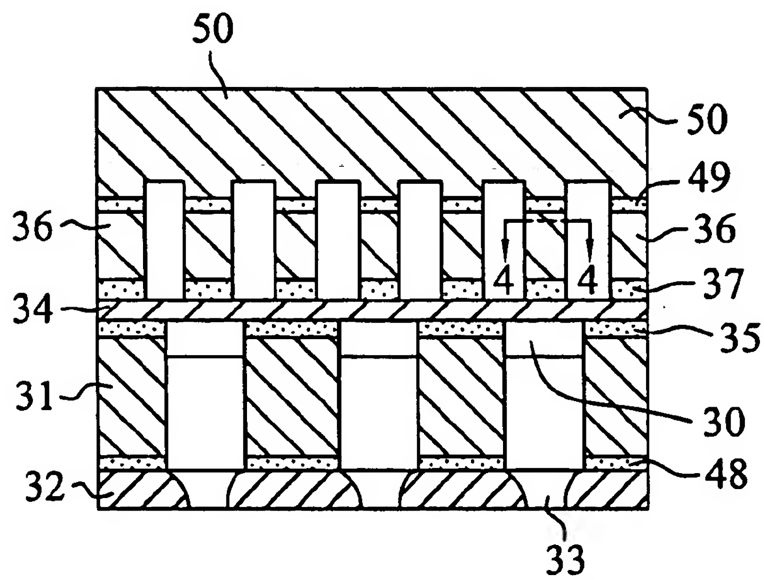
50
50
49
36
36
37
34
35
31
30
32
48
33
4
4

Fig. 2B

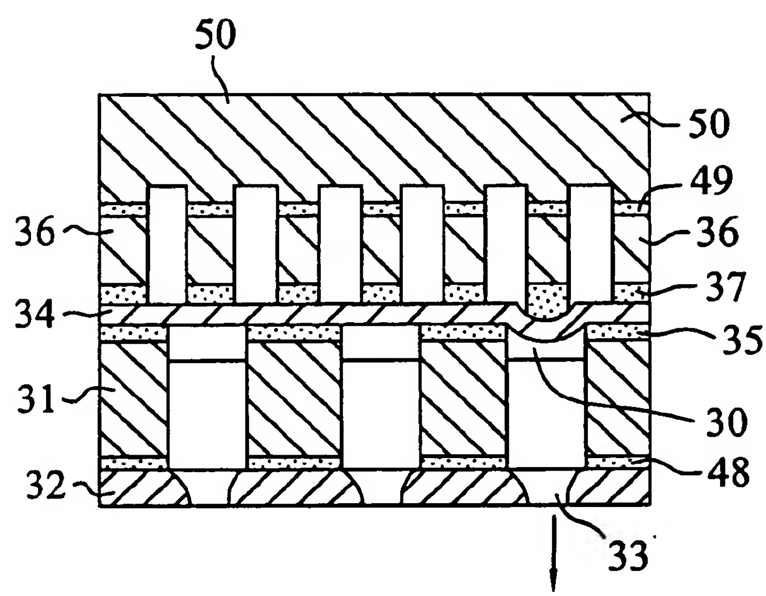
50
50
49
36
36
37
34
35
31
30
32
48
33

Fig. 3

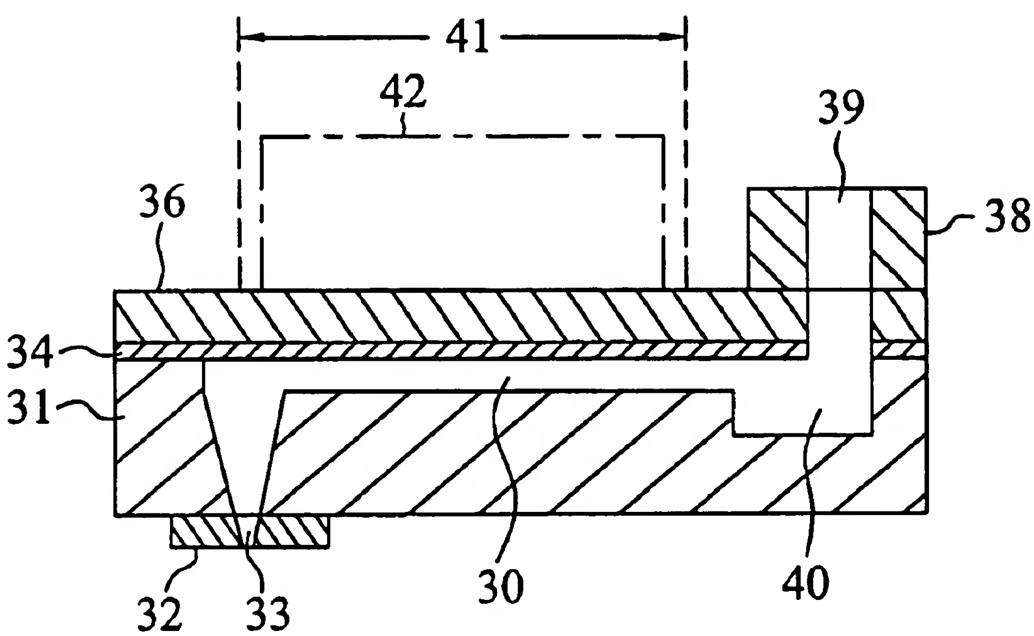

Fig. 4

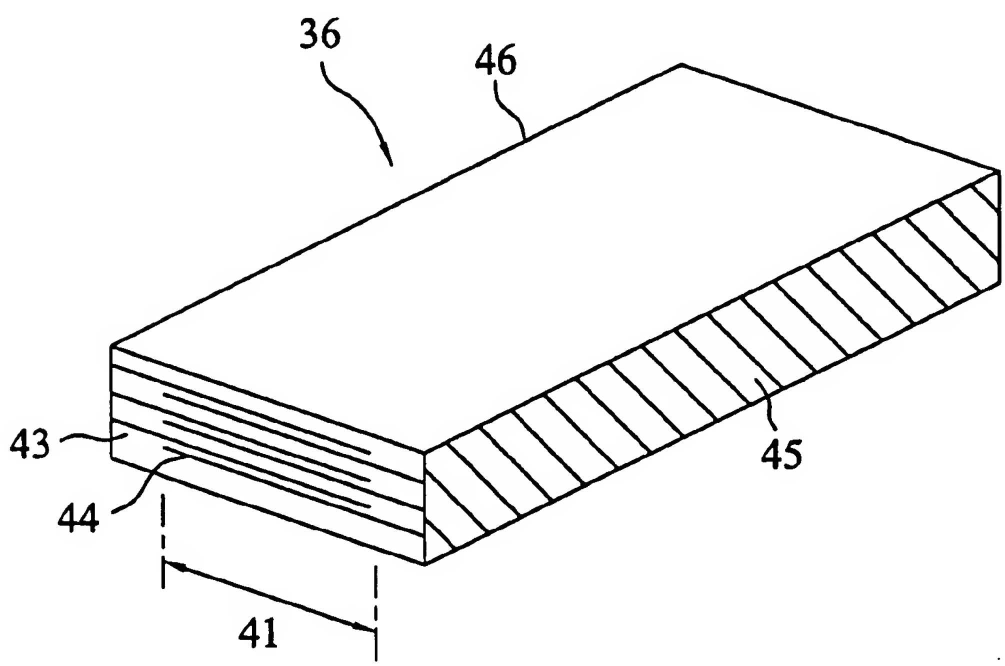

Fig.5

	COMPONENTS WITH LARGE DIFFERENCE IN THERMAL EXPANSION COEFFICIENTS PES AND ALUMINA		COMPONENTS WITH SMALL DIFFERENCE IN THERMAL EXPANSION COEFFICIENTS PZT AND ALUMINA	
	KEPT AT 125°C	THERMAL CYCLE REPEATED	KEPT AT 125°C	THERMAL CYCLE REPEATED
HIGH Tg TYPE ADHESIVE (GLASS TRANSITION TEMPERATURE : HIGHER THAN 125°C)	○	×	◎	◎
MEDIUM Tg TYPE ADHESIVE (GLASS TRANSITION TEMPERATURE : 85°C TO 125°C)	△	×	△	○
LOW Tg TYPE ADHESIVE (GLASS TRANSITION TEMPERATURE : LOWER THAN 85°C)	△	○	△	○

INK JET HEAD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a hot melt type ink jet head for melting solid ink and jetting the melted ink onto print paper for printing thereon. More particularly, the invention relates to an ink jet head capable of preventing the worsening of ink jetting performance attributable to the difference in thermal expansion coefficient of the components for the ink jet head.

2. Description of Related Art

One of the known types of ink jet head (abbreviated where appropriate to "the head" hereinafter) is the so-called thermal type head comprising ink chambers each having a nozzle and incorporating a heating element. In operation, suitably selected heating elements are energized and heated to produce air bubbles in the ink chambers. The pressure exerted by the generated bubbles causes ink to jet out of the nozzles.

Another known type of head is the so-called piezoelectric type head comprising ink chambers on top of which are furnished piezoelectric elements constituted by piezoelectric films made of piezoelectric material and by electrode films for applying voltages to the piezoelectric films. In operation, voltages are fed to suitably selected electrode films displacing the applicable piezoelectric elements through the piezoelectric effect generated therein. The displaced piezoelectric elements in turn change the volumes of the corresponding ink chambers, causing ink to jet out of the chambers through their nozzles. Piezoelectric head printers typically have a hot melt type ink jet head housing solid ink in an ink tank. The solid ink is melted by heat to be jetted out as liquid ink through the nozzles.

A typical hot melt type head that is driven piezoelectrically will now be described with reference to some of the accompanying drawings. Because the conventional head and the head of the invention are basically identical in structure, the drawings used to describe the inventive head are usefully referenced to describe the prior art hereunder.

FIGS. 2A and 2B are partially sectional views of the head according to the invention. FIG. 3 is a partially sectional view in effect when the head of FIGS. 2A and 2B is seen laterally.

A diaphragm (vibrating plate) **34** is made of an aramid film, such as of a highly aromatic polyamide fiber film. On top of the diaphragm **34** are piezoelectric elements **36** composed of piezoelectric material and secured to the diaphragm by an adhesive layer **37**. Below the diaphragm **34** is a cavity plate **31** made of PES (polyether sulfone) and bonded by an adhesive layer **35** to the diaphragm.

A plurality of ink chambers **30** are formed within the cavity plate **31**. Under the cavity plate **31** is a nozzle plate **32** made of nickel and fixed by an adhesive layer **48** to the cavity plate. The nozzle plate **32** has a plurality of nozzles **33** through which ink is jetted out. On top of the piezoelectric elements **36** is a base plate **50** which, made of alumina, supports the piezoelectric elements **36** and is secured by an adhesive layer **49** to the piezoelectric elements. Furthermore, as shown in FIG. 3, the piezoelectric elements **36** are topped with a heater **42** that keeps the ink melted in the ink chambers **30**. When a suitably selected piezoelectric element **36** is energized, it is displaced through the piezoelectric effect generated therein so as to bend the diaphragm **34** into a downward convex shape, as described in FIG. 2B.

The convexly deformed diaphragm changes the volume of the corresponding ink chamber **30** and thereby gives pressure to the ink therein. Under pressure, the ink is jetted out of the chamber through the nozzle **33** in the arrowed direction.

Meanwhile, the adhesive agent that forms the adhesive layers **35**, **37**, **48** and **49** typically has two properties. One is that the adhesive agent develops glass transition at a certain temperature (e.g., 124° C.). The other one is that the adhesive agent deteriorates under the influence of heat.

Suppose that the head is heated by the heater **42** to a temperature (e.g., 125° C.) exceeding the glass transition temperature (e.g., 124° C.) of the adhesive. The trouble, in such a case, is that the adhesive agent softens through glass transition and loses some of its bond strength. This means that separations can occur between the components making up the head and lower the durability of the head. In particular, a lowered adhesive strength between the diaphragm **34** and the cavity plate **31** or the piezoelectric element **36** reduces the rigidity of these components. The reduced component rigidity in turn hampers the displacement of the piezoelectric elements **36** from being precisely transmitted to the diaphragm **34**, thus deteriorating the ink jetting performance and lowering print quality.

As mentioned, the cavity plate **31**, nozzle plate **32**, diaphragm **34**, piezoelectric element **36** and base plate **50** are all composed of different materials. As such, the components have different thermal expansion coefficients. In particular, the cavity plate **31** has a thermal expansion coefficient of 25×10^{-6}, as opposed to 2×10^{-6} for the diaphragm **34**. There is a considerable difference between the cavity plate **31** and the diaphragm **34** in terms of thermal expansion coefficient.

As the head is heated by the heater **42**, the difference in thermal expansion coefficient causes the diaphragm **34** and cavity plate **31** to develop a significant thermal stress therebetween, greater than between any other components. As a result, the diaphragm **34** and cavity plate **31** are especially liable to separate from each other.

The problem caused from such separation, when taking place, is that: it can degrade the vibration characteristic of the diaphragm **34**, lower the ink jetting performance, worsen print quality available with the head, and deteriorate the durability of the head. The disadvantages resulting from the difference in thermal expansion coefficient between the different components of the head are far more serious than those experienced with glass transition of the adhesive agent or with thermally induced performance deterioration. An urgent need has been recognized to circumvent the above-described problems.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to overcome the aforementioned drawbacks and disadvantages of the prior art and to provide a highly durable ink jet head having its components bonded by adhesive agents accommodating the magnitudes of differences in thermal expansion coefficient between the head components, whereby high print quality is made available.

In carrying out the invention, and according to a first aspect thereof, there is provided an ink jet head comprising: a cavity plate incorporating a plurality of ink chambers to be filled with hot melt ink; an energizing element for generating jet energy causing the ink chambers to jet out the hot melt ink from inside; an energy transmitting means for transmitting the jet energy generated by the energizing element to the ink chambers; a nozzle plate having a plurality of nozzles

through which to jet the hot melt ink out of the ink chambers; and a base plate with a manifold for supplying the hot melt ink into the ink chambers; wherein, of the above components of the ink jet head, those with a small difference in thermal expansion coefficient therebetween are bonded together by a first adhesive agent and those with a large difference in thermal expansion coefficient therebetween are bonded together by a second adhesive agent, the first adhesive agent developing glass transition at a temperature exceeding the temperature at which the ink jet head is operated, the second adhesive agent developing glass transition at a temperature below the temperature at which the ink jet head is operated.

In a first preferred structure according to the invention, the second adhesive agent is used to bond together a plurality of component types, one component type having a thermal expansion coefficient substantially at least three times that of any other component type to be bonded thereto.

In a second preferred structure according to the invention, the first adhesive agent has a glass transition temperature higher than the temperature at which the ink jet head is operated, and the second adhesive agent has a glass transition temperature lower by at least 40° C. than the temperature at which the ink jet head is operated.

In a third preferred structure according to the invention, the first and the second adhesive agents are each an epoxy adhesive agent.

According to a second aspect of the invention, there is provided an ink jet head made up of a plurality of components including: a vibrating plate; a piezoelectric element acting as an energizing element which is attached to a first surface of the vibrating plate and which comprises piezoelectric material and electrodes, the electrodes applying voltages to the piezoelectric material to generate a piezoelectric effect therein; a base plate furnished on the other surface of the piezoelectric element with one surface thereof attached to the vibrating plate; a cavity plate attached to a second surface on the other side of the first surface of the vibrating plate and including a plurality of ink chambers with nozzles, the cavity plate being changed in volume in accordance with the displacement of the vibrating plate so as to jet melted ink out of the ink chambers through the nozzles; a nozzle plate attached to the cavity plate and comprising the nozzles connected to the ink chambers; and heating means for keeping the ink melted inside the ink chambers; wherein a first adhesive agent is used to bond the piezoelectric element to the base plate, the cavity plate to the nozzle plate, and the vibrating plate to the piezoelectric element, and wherein a second adhesive agent is used to bond the vibrating plate to the cavity plate, the first adhesive agent developing glass transition at a temperature exceeding the temperature at which the ink jet head is operated, the second adhesive agent developing glass transition at a temperature below the temperature at which the ink jet head is operated.

In any one of the embodiments of the invention outlined above, those components of the ink jet head which have a small difference in thermal expansion coefficient therebetween are bonded together by the first adhesive agent developing glass transition at a temperature exceeding the temperature at which the ink jet head is operated. Those ink jet head components having a large difference in thermal expansion coefficient therebetween are bonded together by the second adhesive agent which develops glass transition at a temperature lower than the temperature at which the ink jet head is operated. In this makeup, while the ink jet head is active, the components secured by the first adhesive agent are prevented from a decline in the adhesive strength therebetween caused by the glass transition of that adhesive, preventing the deterioration in durability of the ink head or in ink jetting performance.

At the temperature at which the ink jet head is operated, the second adhesive agent develops glass transition, producing a softened adhesive layer between the components bonded together by that adhesive agent.

It follows that, with the ink jet head in operation, the softened adhesive agent can absorb a thermal stress caused by the difference in thermal expansion coefficient between the bonded head components. Acting in this manner, the softened adhesive agent prevents separation of the components. In other words, print quality available with the head is improved by minimizing the deterioration of the vibration characteristic of the vibrating plate. This in turn enhances the durability of the head and overall print quality of the printer incorporating the head.

In the above-mentioned second preferred structure of the invention, the first adhesive agent develops glass transition at a temperature higher than the temperature at which the head is operated, and the second adhesive agent has a glass transition temperature lower by at least 40° C. than the temperature at which the head is operated. Thus, if the temperature at which the head is active is illustratively 125° C., the first adhesive agent prevents the separation between the bonded components without developing glass transition, while the second adhesive agent develops glass transition to absorb the thermal stress difference between the glued components, as will be described later with reference to a specific embodiment of the invention.

In the above third preferred structure of the invention, the fact that the first and the second adhesive agents are each an epoxy adhesive agent means little chemical reaction taking place between the ink and the adhesive agents. Unlike some conventional heads using silicone adhesive agents, the inventive head with its components bonded by epoxy adhesives is free of the danger of the adhesive silicone dissolving into the ink and lowering print quality.

In the structure according to the aforementioned second aspect of the invention, the first adhesive agent is used to bond the piezoelectric element to the base plate, the cavity plate to the nozzle plate, and the vibrating plate to the piezoelectric element. Thus, at the temperature at which the head is active, the structure of the invention prevents deterioration of the first adhesive agent and thereby staves off separation between the components bonded together by that adhesive. With the vibrating plate and the cavity plate bonded together by the second adhesive agent, the adhesive layer between these components softens at the temperature at which the head is operated, thereby absorbing the thermal stress difference between the bonded components and preventing their separation.

These and other objects, features and advantages of the invention will become more apparent upon a reading of the following description and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the present invention will now be described in detail with reference to the following figures wherein:

FIG. 1 is a perspective view of some mechanisms in a printer comprising one preferred embodiment of the invention;

FIG. 2A is a partially sectional view of the head;

FIG. 2B is another partially sectional view of the head;

FIG. 3 is a longitudinal sectional view of the head;

FIG. 4 is a partially sectional view showing a typical structure of a piezoelectric element; and

FIG. 5 is a table listing the results of peel tests conducted on various head components.

DESCRIPTION OF PREFERRED EMBODIMENTS

A preferred embodiment of the invention will now be described with reference to the accompanying drawings. What follows is a description of an ink jet head embodying the invention representatively and used by a hot melt type color ink jet printer (abbreviated where appropriate to "the printer" hereunder) which performs color printing by jetting ink of a plurality of colors.

The printer will be first described mechanically by referring to FIG. 1. FIG. 1 is a perspective view of some mechanisms in the printer comprising the head.

As shown in FIG. 1, the printer includes a print head **10** made up of four subordinate heads: a yellow ink head **11** for ejecting yellow ink, a magenta ink head **12** for ejecting magenta ink, a cyan ink head **13** for ejecting cyan ink, and a black ink head **14** for ejecting black ink. Each of the heads **11** trough **14** is equipped with an ink tank housing solid ink.

The print head **10** is mounted on a carriage **21** penetrated by a guide shaft **22** positioned in the crosswise direction of print paper **20**. The carriage **21** is attached to an endless belt **23** located underneath and along the guide shaft **22**. The endless belt **23** is engaged with a pulley **25** on the shaft of a motor **24**. In this setup, the revolutions of the motor **24** cause the carriage **21** to reciprocate along the guide shaft **22** in the crosswise direction of the print paper **20**.

A timing slit member **26** with a plurality of slits engraved thereon is furnished underneath and parallel to the guide shaft **22**. In front of and below the carriage **21** is an encoder element **27** for reading the number of slits from the timing slit member **26**. The print paper **20** is fed vertically, pinched between paper feed rollers rotated by a paper feed motor and holding rollers **28** placed opposite to the paper feed rollers.

The structure of the heads **11** through **14** will now be described with reference to FIGS. **2A** through **4**. Since the four heads are structurally identical, the head **11** alone will be described representatively.

FIGS. 2A and 2B are partially sectional views of the head **11**. In the figures, the lower plane of the head **11** faces the printer paper **20** (see FIG. **1**). FIG. **3** is a longitudinal sectional view of the head **11** of FIG. **2A** as viewed laterally, with the base plate omitted.

As depicted in FIG. 2A, the head **11** has a plurality of ink chambers (cavities) **30** for housing ink. The ink chambers **30** are separated from one another by walls of the cavity plate **31**. An adhesive layer **48** attaches a nozzle plate **32** to the underside of the ink chambers **30** and cavity plate **31**. The nozzle plate **32** has a plurality of nozzles **33** formed penetratingly therethrough. The nozzles **33** allow ink to be jetted out of the ink chambers **30**. An adhesive layer **35** attaches a diaphragm (vibrating plate) **34** to the top of the ink chambers **30** and cavity plate **31**.

In this embodiment, as shown in FIG. 2A, each ink chamber **30** measures 0.22 mm wide and 0.15 mm high, and each cavity plate **31** formed by PES measures 0.119 mm wide and 2.5 mm thick. The nozzle plate **32** is made of nickel. Each nozzle **33** at its lowest part measures 55 μm in diameter. The diaphragm **34** is formed by an aramid film, is

9 μm thick, and has a thermal expansion coefficient of 2×10^{-6}. The cavity plate **31** has a thermal expansion coefficient of 25×10^{-6}, compared with 14×10^{-6} of the nozzle plate **32**.

Past experiments involving materials of varied thermal expansion coefficients have shown that if the thermal expansion coefficient of one member is approximately at least three times that of any other member bonded thereto, a thermal stress is known to develop therebetween, causing the bonded members to separate.

As shown in FIG. 2A, an adhesive layer **37** attaches a plurality of piezoelectric elements **36** acting as plate-like energizing elements to the top of the diaphragm **34**. Another adhesive layer **49** bonds a base plate **50** supporting the piezoelectric elements **36** to their top. A manifold plate **38** to form ink injection holes **39** is furnished behind the base plate **50**, as illustrated in FIG. **3**. The underside of the ink injection holes **39** has a manifold **40** penetrating the ink chambers **30**. The top of each piezoelectric element **36** is provided with a heater **42** as heating means to keep the ink melted inside the ink chamber **30**. In FIG. **3**, the portion approximately corresponding to the ink chamber **30** constitutes an active part **41**, i.e, a part in which the piezoelectric element **36** produces displacement through the piezoelectric effect.

With this embodiment, as shown in FIG. 2A, each piezoelectric element **36** is made of a piezoelectric material such as PZT (lead-zirconium-titanate) and measures 0.08 mm wide and 0.5 mm thick. The center-to-center pitch of the cavity plate **31** is 0.339 mm, and each ink injection hole **39** measures 2.0 mm in diameter. The manifold **40** is 1.5 mm deep and 2.0 mm wide, while the active part **41** measures 4.0 mm in width. The piezoelectric elements **36** have a thermal expansion coefficient of 2×10^{-6} as opposed to 5×10^{-6} of the base plate **50**.

The adhesive layers **37**, **48** and **49** are each formed by an epoxy adhesive agent having a glass transition temperature Tg of 127° C., higher than the temperature of the head in active use (e.g., 125° C.). That is, the diaphragm **34** and piezoelectric elements **36** have the same thermal expansion coefficient. There is less than a threefold difference in thermal expansion coefficient between the cavity plate **31** and the nozzle plate **32**, as well as between the piezoelectric element **36** and the base plate **50**.

Because there is little difference in thermal stress between the diaphragm **34** and the piezoelectric elements **36**, their separation will not be caused by the thermal stress difference. However, a separation of these components can still result from deterioration of the adhesive agent attributable to its glass transition. Such a separation is forestalled by an adhesive agent having a glass transition temperature (e.g., 127° C.) higher than the head operating temperature (e.g., 125° C.), used between the diaphragm **34** and the piezoelectric elements **36**.

Meanwhile, the adhesive agent forming the adhesive layer **35** between the diaphragm **34** and the cavity plate **31** is an epoxy adhesive agent illustratively having a glass transition temperature Tg of, for example, 79° C., lower by at least 40° C. than the temperature (125° C.) of the head in active use. There occurs more than a threefold difference in thermal expansion coefficient between the cavity plate **31** and the diaphragm **34**, hence a large thermal stress is generated therebetween. In this case, the adhesive layer **35** with its glass transition temperature Tg lower by at least 40° C. than the typical head temperature of 125° C. softens by developing glass transition at that head temperature. The softened adhesive layer **35** absorbs the thermal stress generated

between the cavity plate **31** and the diaphragm **34**, thereby preventing their separation.

According to the inventor's experiments, each adhesive layer is preferably formed so as to have a thickness of 3 to 25 μm, in view of both maintaining high adhesive strength between the bonded components and absorbing the thermal stress therebetween. More preferably, the adhesive layer should measure 5 to 20 μm thick, or more preferably 5 to 10 μm thick. The best results are obtained when the adhesive layer measures 5 μm in thickness. Furthermore, the use of epoxy adhesives is preferred because they are unlikely to react chemically with the ink. Unlike silicone adhesive agents, epoxy adhesives do not dissolve into the ink through chemical reaction and therefore do not blur the contours of printed portions on plastic resin sheets and the like.

The structure of the piezoelectric element **36** will now be described with reference to FIG. **4**. FIG. **4** is a partially sectional view showing a typical structure of the piezoelectric element **36**.

As shown in FIG. **4**, the piezoelectric element **36** is formed by alternately stacking piezoelectric films **43** made of piezoelectric material and electrode films (internal electrode) **44**. In this makeup, the piezoelectric films **43** are polarized in the stacking direction. Although not shown in FIG. **4**, between 10 to 20 layers constitute the piezoelectric element **36** in practice. Both ends of the piezoelectric element **36** are furnished with edge electrodes **45** and **46**.

In this embodiment, each piezoelectric film **43** measures approximately 30 μm in thickness. The electrode films **44** and edge electrodes **45** and **46** are each formed by silver palladium (70% silver, 30% palladium) to have a thickness of 2 to 3 μm.

The ink used by the embodiment contains paraffin wax as its major ingredient. Any one of three kinds of ink (A, B, C), for example, is used: ink A with a softening point of 56° C. to 58° C. and a melting point of 69° C. to 71° C.; ink B with a softening point of 62° C. to 64° C. and a melting point of 76° C. to 78° C.; and ink C with a softening point of 81° C. to 86° C. and a melting point of 92° C. to 94° C. The appropriate kind of ink is selected illustratively by taking into account the viscosity at the temperature of the printer in operation (e.g., 2 to 50 cPs), surface tension, chromaticity after printing, and post-printing saturation.

In operation, a head driving circuit applies a voltage to each electrode film **44** producing the piezoelectric effect in each piezoelectric film **43**. This bends the diaphragm **34** into a downward convex shape as shown in FIG. 2B, applying pressure to the ink chamber **30** and causing the ink to jet out through the nozzle **33**. The heads **11** through **14** may each be operated singly to perform monochromatic printing, or may be selectively activated in combination to jet out simultaneously a plurality of colors of ink to carry out medium tone printing.

Described below with reference to FIG. **5** are the results of peel tests conducted on the components constituting the head **11**.

The peel tests were carried out on two categories of components: components with a large difference in thermal expansion coefficient therebetween, composed of PES (having a thermal expansion coefficient of 25×10^{-6}) and alumina (coefficient: 5×10^{-6}); and components with a small difference in thermal expansion coefficient therebetween, formed by piezoelectric material PZT (2×10^{-6}) and alumina (5×10^{-6}).

For the peel tests, a 5 mm×40 mm alumina board was bonded to the middle of a 20 mm×20 mm PES board. Four wires were attached to the four corners of the PES board, and the wires were pulled by a tension spring balance at a tensile load of 70 g for the tests. The peel tests were also carried out on another setup involving a PZT board glued to an alumina board.

Three kinds of adhesive agents were used: an adhesive with a glass transition temperature Tg higher than 125° C. (high Tg type), an adhesive with a glass transition temperature Tg between 85° C. and 125° C. (medium Tg type), and an adhesive with a glass transition temperature Tg lower than 85° C. (low Tg type). Each adhesive agent was stamped to a thickness of 20 μm. Two ambient situations were prepared into which the components under test were exposed. In one situation, the temperature of 125° C. was kept for 132.5 hours. The other situation was one in which a thermal cycle of heating up to 125° C. followed by natural cooling to the room temperature of 25° C. was repeated dozens of times at intervals of several minutes.

In the table of FIG. **5**, a double circle (◎) means total absence of separation, a single circle (○) denotes the presence of few separations, a triangle (Δ) indicates that overall quality was satisfactory despite some separations, and a cross (×) points to the occurrence of numerous separations.

As is evident in FIG. **5**, the best results were acquired in the two ambient situations when the high Tg type adhesive agent was used to bond together the components with the small difference in thermal expansion coefficient therebetween, and the low Tg type adhesive agent was employed to glue the components having the large difference in thermal expansion coefficient therebetween.

It is also clear from FIG. **5** that the high Tg type adhesive agent having a glass transition temperature higher than the head temperature is most desirable for bonding together the components with the small difference in thermal expansion coefficient therebetween. However, the durability of the head and the ink jetting performance were fairly satisfactory even where the medium Tg type adhesive agent (with a glass transition temperature a little lower than the head temperature) or the low Tg type adhesive agent (with a glass transition temperature definitively lower than the head temperature) was used to bond together the components with the small difference in thermal expansion coefficient therebetween.

As described, the embodiment utilizes the high Tg type adhesive agent to bond together the components with the small difference in thermal expansion coefficient therebetween, and the low Tg type adhesive agent to glue the components having the large difference in thermal expansion coefficient therebetween. This prevents separations between the head components while enhancing the head durability and improving the ink jetting performance at the same time.

Of the piezoelectric element **36**, diaphragm **34** and cavity plate **31** significantly affecting the ink jetting performance, the diaphragm **34** and cavity plate **31** with a considerable difference in thermal expansion coefficient therebetween are preferably glued together using an adhesive agent capable of absorbing the thermal stress generated between the bonded components. This also contributes to improving the durability of the head and boosting the ink jetting performance at the same time. The head components not seriously affecting the ink jetting performance or those with only a limited difference in thermal expansion coefficient therebetween may be preferably bonded together by use of an adhesive agent having a high glass transition temperature.

The head having the above-described features may be applied illustratively to the printer. When equipped with the inventive head, the printer provides high quality printing.

As many apparently different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the appended claims.

What is claimed is:

1. A hot melt ink ink jet head comprising:

a cavity plate incorporating a plurality of ink chambers to be filled with hot melt ink;

an energizing element for generating energy for jetting the hot melt ink from said ink chambers;

an energy transmitting element for transmitting the energy generated by said energizing element to said ink chambers;

a nozzle plate having a plurality of nozzles through which said hot melt ink is jetted from said ink chambers; and

a base plate with a manifold for supplying said hot melt ink into said ink chambers;

wherein said energizing element and said base plate, said cavity plate and said nozzle plate, and said energy transmitting element and said energizing element respectively, have a small difference in thermal expansion coefficient therebetween and are bonded together by a first adhesive agent, said first adhesive agent developing glass transition at a temperature exceeding an operating temperature of said ink jet head, said energy transmitting element and said cavity plate have a large difference in thermal expansion coefficient therebetween and are bonded together by a second adhesive agent, and said second adhesive agent developing glass transition at a temperature below said operating temperature and thereby softens at said operating temperature.

2. The ink jet head according to claim 1, wherein said second adhesive agent is used to bond together a plurality of components of said ink jet head, one component having a thermal expansion coefficient substantially at least three times that of a second component to be bonded thereto.

3. The ink jet head according to claim 1, wherein said second adhesive agent has a glass transition temperature lower by at least 40° C. than said operating temperature.

4. The ink jet head according to claim 1, wherein said first and said second adhesive agents are an epoxy adhesive agent.

5. The ink jet head according to claim 1, further comprising a heater for melting said hot melt ink.

6. The ink jet head according to claim 1, wherein an adhesive layer formed by said second adhesive agent is 3 to 25 μm thick.

7. A hot melt ink ink jet head made up of a plurality of components including:

a vibrating plate;

a piezoelectric element which is attached by a first adhesive agent to a first surface of said vibrating plate and which comprises piezoelectric material and electrodes, said electrodes applying voltages to said piezoelectric material to generate a piezoelectric effect therein;

a base plate furnished on a first surface of said piezoelectric element with a second surface of said piezoelectric element attached to said vibrating plate;

a cavity plate attached to a second surface of said vibrating plate and including a plurality of ink chambers, said cavity plate being changed in volume in accordance with a displacement of said vibrating plate so as to jet hot melt ink out of said ink chambers;

a nozzle plate attached to said cavity plate and comprising nozzles connected to said ink chambers; and

a heater for keeping the ink melted inside said ink chambers;

wherein said vibrating plate and said cavity plate have a large difference in thermal expansion coefficient therebetween and are bonded together by a second adhesive agent, said second adhesive agent developing glass transition at a temperature below an operating temperature of said ink jet head and softening at said operating temperature.

8. The ink jet head according to claim 7, wherein components of said ink jet head with a small difference in thermal expansion coefficient therebetween are bonded together by said first adhesive agent, said first adhesive agent developing glass transition at a temperature exceeding said operating temperature.

9. The ink jet head according to claim 8, wherein said first adhesive agent is used to bond said piezoelectric element to said base plate, said cavity plate to said nozzle plate, and said vibrating plate to said piezoelectric element, and wherein said second adhesive agent is used to bond said vibrating plate to said cavity plate.

10. The ink jet head according to claim 7, wherein said glass transition temperature of said second adhesive agent is lower by at least 40° C. than said temperature at which said ink jet head is operated.

11. The ink jet head according to claim 7, wherein said second adhesive agent is used to bond together a plurality of components, one component having a thermal expansion coefficient substantially at least three times that of any other component to be bonded thereto.

12. The ink jet head according to claim 7, wherein each of said first adhesive agent and said second adhesive agent are epoxy adhesive agents.

13. A hot melt ink ink jet head comprising:

a cavity plate incorporating a plurality of ink chambers to be filled with hot melt ink;

an energizing element for generating energy causing said ink chambers to jet out said hot melt ink from inside;

an energy transmitting element for transmitting the energy generated by said energizing element to said ink chambers;

a nozzle plate having a plurality of nozzles through which to jet said hot melt ink out of said ink chambers; and

a base plate with a manifold for supplying said hot melt ink into said ink chambers;

wherein said energy transmitting element and said cavity plate have a large difference in thermal expansion coefficient therebetween and are bonded together by a second adhesive agent which develops glass transition at a temperature below an operating temperature of said ink jet head and thereby softens at said operating temperature, wherein a first adhesive agent bonds said energizing element to said base plate, said cavity plate to said nozzle plate, and said energy transmitting element to said energizing element.

14. The ink jet head according to claim 13, further comprising a heater for melting said hot melt ink.

15. The ink jet head according to claim 13, wherein the adhesive layer formed by said second adhesive agent is 3 to 25 μm thick.

16. The ink jet head according to claim 13, wherein said glass transition temperature of said second adhesive agent is lower by at least 40° C. than said temperature at which said ink jet head is operated.

17. The ink jet head according to claim 13, wherein said first and second adhesive agents are an epoxy adhesive agent.

* * * * *